EVOLUTION

- Evolution (Gk. *e* - out, *volvere* - to roll) is unrolling or unfolding of nature that brings about an orderly change from one form or condition to another resulting in descendents becoming different from ancestors.
- Evolutionary biology is the study of history of development of newer forms of life from the pre-existing ones in various periods of time on earth. The life has evolved into many forms since its origin on earth.

ORIGIN OF LIFE

- Origin of life or **biopoiesis** is the development of living matter from complex organic molecules that are themselves non-living but self replicating. Before the origin of life, origin of universe must be considered.
- Most accepted theory to explain the origin of universe is the big-bang theory which was proposed by Abbe **Lemaitre in 1931**. According to this theory, universe had an explosive beginning. Universe originated about 20 billion years ago by a big bang (thermonuclear explosion) of a dense entity. Then the universe expanded and hence the temperature came down. Hydrogen the elementary atom fused into progressively heavier atoms of different kinds of elements found today.
- To explain origin of life, earlier it was believed that some special power created life. It is called **theory of special creation.**
- According to another hypothesis called **Nebular hypothesis** which was given by **Kant** (1755) – **Leplace** (1796), our solar system was probably created about **4.5 to 5 billion years ago** when the gaseous cloud called solar nebula was formed.
- Another theory termed as **cosmozoic theory** was also formulated. According to it **primitive life** or **panspermia** came to earth from some other planet in the form of microbes or spores. But extreme environment of the interstellar space must have killed these panspermia before reaching earth. Hence this theory was discarded.
- **Theory of spontaneous generation** believes that under certain conditions nonliving substances give rise to living beings spontaneously. It was supported by many old scholars like **Thales, Anaximander, Aristotle, Plato, Epicurus,** etc.
- However, living beings are neither produced spontaneously nor created. Instead, life comes from pre-existing life or *omne vivum e vivo*. The phenomenon is called biogenesis (Gk. bios-life, genesis - birth). **Biogenesis** was proved by the work of three scientists - **Redi** (1668), **Spallanzani** (1767) and **Pasteur** (1867).
- **Louis Pasteur** (in 1864) used swan-neck flasks and prepared a meat broth in these flasks, and boiled them for several hours.
- He then left the flask unsealed on a laboratory bench and there was a free exchange of air with the environment, so the system did not lack oxygen.
- Still, the flask remained free of microbial contamination for months.
- This experiment thus **disproved** the **concept of spontaneous generation** completely.
- **The modern hypothesis of origin of life was formulated** by **Haeckel.** This idea was elaborated in the chemical theory (in 1920s) by two workers independently: a Russian biochemist **A.I. Oparin** and an English biologist **J.B.S. Haldane.** It was summarized by Oparin in his book **"The Origin of Life"** published as an English edition in 1938.
- **Oparin and Haldane state that –**
  - Spontaneous generation of life under the present environmental conditions is not possible.
  - Earth's surface and atmosphere during the first billion years of its existence were radically different from today's conditions.
- Earth's **initial atmosphere was a reducing one. Abiogenesis** occurred about 3.7 billion years ago.
- The Oparin-Haldane theory (also called **protobiogenesis**) was experimentally supported by **Stanley Miller** in 1953 and separated the entire process into the following steps: **origin of Earth and its primitive atmosphere; chemical evolution** (chemogeny) and **biological evolution.**
- The conditions on earth were – high temperature, volcanic storms, reducing atmosphere containing CH_4, NH_3, etc. In 1953, S.L. Miller, an American scientist student of Harold C.Urey created similar conditions in a laboratory scale. He created electric discharge in a closed flask containing CH_4, H_2, NH_3 and water vapour at 800°C. He observed formation of amino acids. In similar experiments others observed, formation of sugars, nitrogen bases, pigment and fats. Analysis of meteorite content also revealed similar compounds indicating that similar processes are occurring elsewhere in space. With this limited evidence, the first part of the conjectured story, *i.e.*, chemical evolution was more or less accepted.

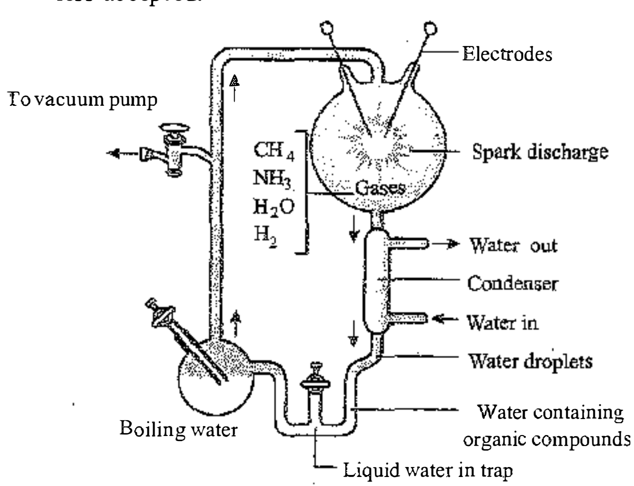


Fig.: Diagrammatic representation of Miller's experiment

- The synthesis of carbohydrates, fats and amino acids and other complex organic substances probably occurred in sea, which had been described by Haldane as **'The hot dilute soup'. The formation of protein molecule is considered a land mark in the origin of life.**

PROTOCELL MODELS

- **Proteinoids :** These are polypeptides synthesized by heating a mixture of aminoacids from 160° to 210°C for several hours.
- The large organic molecules which were synthesized abiotically on primitive earth later came together, and due to intermolecular attraction, they formed large colloidal aggregates. Such water bound aggregates have been named **microspheres** by **Sydney Fox.**
- **Coacervate** is an aggregate of macromolecules, such as proteins, lipids, and nucleic acids, that form a stable colloid unit with properties that resemble living matter. Many are coated with a lipid membrane and contain enzymes that are capable of converting such substance as glucose into more complex molecules, such as starch.
- **Biogenesis :** The principle that a living organism can only arise from other living organisms similar to itself (*i.e.* that like gives rise to like) and can never originate from nonliving material.
- After the origin of life in the form of giant molecules, self replicating aggregates of macromolecules like nucleic acids and proteins, biological evolution started. It resulted in formation of various complex biological forms that we can see today.

BIOLOGICAL EVOLUTION

- The first living organisms originated among organic molecules and in oxygen free atmosphere (reducing atmosphere). They presumably obtained energy by the fermentation of some of these organic molecules. They were anaerobes capable of respiration in the absence of oxygen. They depended on the existing organic molecules for their nutrition and thus they were **heterotrophs**.
- When the supply of existing organic molecules was exhausted, some of the heterotrophs might have evolved into **autotrophs**. These organisms were capable of producing their own organic molecules by chemosynthesis or photosynthesis.
- The organisms performing chemosynthesis are called **chemoautotrophs**. They were anaerobs. Chemoautotrophs developed the ability to synthesise organic molecules from inorganic raw materials.
- The photosynthetic organisms, the photoautotrophs, developed the pigment chlorophyll by combination of simple chemicals. They prepared organic food by using solar energy captured with the help of chlorophyll. They lacked the biochemical pathways to produce oxygen. They were still anaerobs and utilized hydrogen from sources other than water.
- At later stage, oxygen releasing photosynthetic organisms developed. These were similar to the existing blue green algae (**cyanobacteria**). They used water to get hydrogen and released oxygen.
- Aerobic respiration evolved sufficient oxygen in the primitive atmosphere. The prokaryotes gradually modified to adapt themselves according to new conditions. They developed a true nucleus and other specialized cell organelles. Thus free-living eukaryotic cell-like organisms originated in the ancient ocean, presumably about 1.5 billion years ago. Primitive eukaryotes led to the evolution of protists, plants, fungi and animals.
- Life was present on earth about 3.9 billion years ago. However, the oldest microfossils discovered so far are that of photosynthetic cyanobacteria that appeared 3.3 to 3.5 billion year ago.

EVIDENCES OF EVOLUTION

- Evolution or organic evolution or bioevolution is 'descent with modification', (Darwin) or 'continuity of life with constant modifications.
- The convincing evidences supporting this are: comparative morphology, anatomy and embryology, paleontology, geographical distribution, taxonomy, connecting links, cytology, biochemistry, physiology and genetics etc.

Morphological and anatomical evidences

- They include related organ systems, homology, analogy, adaptive radiation, adaptive convergence, vestigial organs and atavism etc.
- Respiratory system of all terrestrial vertebrates has two lungs, a trachea, a larynx, nasal chambers and nostrils. Likewise, the blood vascular system of all vertebrates contains a heart, arteries, veins and lymph vessels. The presence of similar organ systems indicates a common ancestry.
- **Homology** is the similarity between organs of different animals based on common structural organization or common embryonic origin. **Homologous organs** have common origin and are built on the same fundamental pattern, but perform varied functions and have varied appearances. *E.g.*, Seal flipper, bird wing, bat wing, horse fore limb, and human arm look different, perform different functions but exhibit same structural plan.
- Legs and mouth parts of various insect groups, thorns and tendrils of some plants, are other examples of homology. Homology confirms **divergent evolution** or **adaptive radiation**.
- **Adaptive radiation** represents evolution of new forms in several directions from the common ancestral type (divergence). *E.g.*, the limbs in mammals are variously adapted for climbing, flying, running, swimming or burrowing etc.

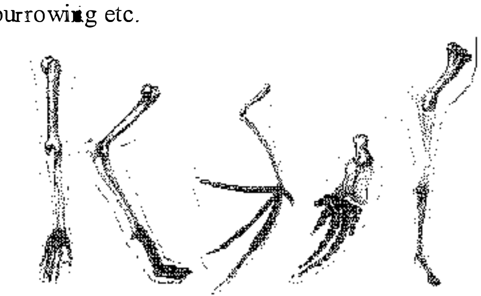


Fig.: Homology among the bones of the forelimb.

- **Analogous organs** are totally different in basic structure and developmental origin, but perform the same function, *e.g.*, wings of a butterfly (chitinous), bird (feathered), pterodactyl and bat (skin fold) serve the same purpose of uplifting the body in air but differ in structure. Other examples are fins of fishes and flippers of whale, cephalopod and vertebrate eyes, etc. In plants, leaves and cladodes, tuberous root and potato etc. are analogous organs.

- Study of analogous organs illustrates the occurrence of **convergent evolution**.
- **Vestigial or rudimentary organs** are the useless remnants of structures or organs which might have been large and functional in the ancestors. Vermiform appendix in man, nictitating membrane, auricular muscles, vestigial tail in vertebrates, wisdom teeth, mammary glands in males and body hair are some of its examples.

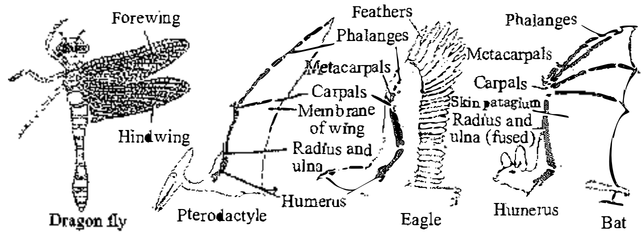


Fig : Analogy in the wings of insect, pterodactyle, bird and bat (Apparently similar but constructed on different patterns).

- **Atavism** or reversion is the reappearance of a certain ancestral, not parental structure which has either completely disappeared or greatly reduced. Occurrence of short tail in some babies, additional mammae, larger canine teeth, power of moving pinna, very long and dense hair etc. are some of the examples of atavism in humans.

Embryological evidences

- Comparative embryology also provides evolutionary evidences. Homology in early embryonic development and fate of three germ layers establish a close relationship among the animals and suggests that all have evolved in a series from a common ancestor. Homology in the embryos of closely related vertebrates, indicates evolutionary relationship of the adult vertebrates.
- **Haeckel** formulated the "**Recapitulation theory or Biogenetic Law**" regarding this. This theory says that "**ontogeny recapitulates phylogeny**", *i.e.* life history recapitulates evolutionary history. This means an organism repeats its ancestral history during its development. For example in the development of frog a fish like tailed larva is formed, which swims with the tail and respires by gills. This indicates that the frog has been evolved from a fish like ancestor.
- **Von Baer's (Father of Modern Embryology)** principles of embryonic differentiation constitute a better guide to embryological evidences for evolution.
- During metamorphosis, ascidian tadpole loses all the chordate features like notochord, nerve cord and myotomes. This is called **retrogressive metamorphosis**. Larva has helped in determining its chordate nature.
- Retention of larval features (**neoteny**) provides evidences in favour of evolution through natural selection. **Axolotl larva** is the classical example of neoteny in which adult retains the embryonic traits. In some animals (salamanders) gonadal development occurs in immature larval or preadult animal (**precocious development**).

Paleontological evidences

- **Palaeontology** is the study of past life based on the fossil records. It furnishes the most direct and most reliable evidence for evolution. The term fossil (Latin, *fossilum*, something to dug out) refers to the petrified remains or impressions of organisms that lived in past and got preserved in sedimentary rocks.
- Bones, teeth, shell, impression or imprints in the soft mud, or the moulds and casts of entire organism are some examples of fossils. The study of fossil plants is called palaeobotany while the study of fossil animals is called **palaeozoology**. From the fossil records it has been concluded that evolution has taken place from simple to complex in a gradual manner.
- The different methods of fossilization are – intact preservation, petrification, moulds and casts, impressions, mummies, tracks and trails etc. The media in which fossils occur, include sedimentary rocks, amber, asphalt, volcanic ash, ice, peat bogs, sand and mud.
- Age of a fossil is determined by dating of rocks in which it was found. The dating of rocks is called **geochronology** and dating system is called "**clock of rocks**".
- Geological time is a chronological order or history of evolution based upon the study of fossils. It has been divided into **eras, periods and epochs**. The fossil studies have given evidences of several mass extinctions. Mass extinction is death and disappearance (extinction) of large groups of plants and animals over a short span of time. It might be due to crash of a meteor or comet with earth, or due to the drifting, coalescing and breaking apart of continents.
- This shapes the overall pattern of **macroevolution**. The largest mass extinction came at the end of permian, about **250 million years ago**. The most well-known extinction occurred at the boundary between the cretaceous and tertiary periods. This, called the **K/T boundary**, is dated around **65 million years ago**. This extinction eradicated the dinosaurs.

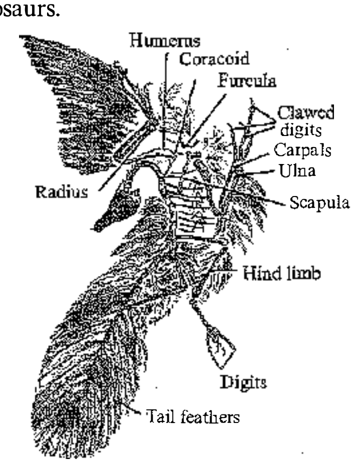


Fig.: *Archaeopteryx* fossil

Connecting links

- Living organisms possessing characters of two different groups of organisms are known as the **connecting links**. Examples – Viruses : between non living and living, *Euglena*: between plants and animals, *Peripatus*: between annelida and arthropoda, *Balanoglossus*: between non-chordates and chordates, *Chimaera*: between cartilaginous and bony fishes. They give a hint about evolution of one group from the other. On the other hand fossils that show combined features of two groups are termed missing links, *e.g.*, *Archaeopteryx*.

Molecular and physiological evidences

- Similarities in the **biochemical composition, reactions and physiological activities** are the most convincing evidences of common ancestry. Aspects of biochemistry that indicate biochemical affinity are **metabolic processes, enzymes, hormones, blood and lymph, blood proteins, blood groups and molecular homology.**
- Blood proteins tests have shown that the man is nearest to the great apes (gorilla and chimpanzee), and next nearest, in order, are the old world monkeys, the new world monkeys and the tarsiers.
- Genetics or "science of heredity" shows final line of evidence for evolution. Genetic mutations provide raw material for evolution and give rise to new species. Hereditary variations also occur due to genetic recombination. The latter causes hybridization. Examples of hybridization and mutations are available which show that evolution has taken place.
- Pattern of transmission of characters is also similar in various organisms. It shows inter-relationship among different living beings.
- Man has developed many varieties of useful animals (*e.g.*, high milk yielding cows, ancon sheep, horses, hornless cattle etc.) and crops (*e.g.*, wheat, rice, cotton, etc.). No doubt, the varieties of each of the animals and plants still belong to the same species, but it is possible that if the development of such variations is continued, there would emerge forms which would be regarded new species. These animals and plants have, thus, undergone change, and this is evolution.

Table : Geological Time Scale with notes on events in the evolution of life and environment

Era	Period	Epoch	Duration in millions of years	Time from beginning of period to present (Millions of years)	Geological and climatic conditions	Plant life	Animal life
Coenozoic (Age of mammals)	Quaternary	Recent	0.025	0.025	End of last ice age, climate warmer, climatic zones distinct.	Dominance of herbs.	Age of man, development of human cultures.
		Pleistocene	1	1	Periodic continental glaciers in north.	Increase of herbs, great decrease of woody plants.	Age of man, extinction of many large mammals.
	Tertiary	Pliocene	11	12	Cool and temperate climate away from equator, continuous rise of mountains of Western North America.	Decline of forests, spread of herbs and grassland.	Abundant mammals, man evolving, elephant, horses and camels almost like modern models.
		Miocene	13	25	Cooling of climate.	Development of grasses, reduction of forests.	Mammals at height of evolution, first man like apes.
		Oligocene	11	36	Lands lower, climate warmer.	Worldwide tropical forests, rise of monocots and flowering plants.	Archaic mammals extinct, appearance of modern mammals.
		Eocene	22	58	Zoned climatic belts well established.	Extension of angiosperms.	Placental mammals diversified and specialized, hoofed mammals and carnivores established.
		Palaeocene	5	63	Development of climatic belts.	Modernization of angiosperms.	Evolutionary explosion of mammals.
Rocky Mountain Revolution (Little destruction of fossils)							
Mesozoic (Age of reptiles)	Cretaceous	–	72	135	Birth of modem reptiles, development of climatic diversity.	Rise of flowering plants especially monocotyledons, decrease of gymnosperm.	Dinosaurs reached peak, became extinct, toothed birds became extinct, beginning of teleost fishes and modem birds, archaic mammals common.
	Jurassic	–	45	180	Culmination of world-wide warm climates.	Cycads and conifers common, appearance of first known flowering plants.	Dominance of dinosaurs, appearance of first toothed birds, spre-ad of reptiles, rise of insectivorous marsupials.
	Triassic	–	50	230	Continents exposed, worldwide subtropical climatic.	Gymnosperms dominant, declining towards end, extinction of seed fern.	Transition of reptiles to mammals, rise of progressive reptiles and egg laying mammals, extinction of primitive amphibians.

Appalachian Revolution (Some loss of fossils)							
Palaeozoic (Age of Ancient Life)	Permian	–	50	280	Rise of continents, climate became arid and varied, glaciation in Southern hemisphere.	Dwindling of ancient plants, decline of lycopods and horse tails.	Extinction of ammonites and trilobites, abundance of primitive reptiles, appearance of mammals- like reptiles, decline of amphibia.
	Pennsyl-vanian	–	40	320	Uniform climate throughout world.	Great forests of seed-ferns and gymno-sperms (Great tropical coal forests).	Amphibians dominant on land, insects common, appearance of first reptiles.
	Mississippian (Carboniferous)	–	25	345	Climate uniform, and humid at first, cooler, later as land rose, spread of tropical seas.	Mosses and seed ferns dominant, gymnosperms increasingly widespread. (Early coal forests).	Rise of insects, sea lilies at peak, spread of ancient sharks.
	Devonian		60	405	Broad distribution of uniform climates, increased temperature.	First forests, first gymnosperms and first known liverworts, horse tails and ferns.	Diversification in fishes, sharks and lung fishes abundant, evolution of amphibians.
	Silurian	–	20	425	Slight climate cooling, extensive continental seas.	First known land plants-clubmosses, algae dominant.	Wide expansion of invertebrates, first insects, rise of fishes.
	Ordovician	–	75	500	Climate became progressively warmer.	Algae, fungi and bacteria, first fossils of plant life.	Invertebrates numerous and varied, most modern phyla established.
	Cambrian	–	100	600	Warm climate, great submergence of land.	Land plants probably first appeared, marine algae abundant.	First indication of fishes, corals and trilobites abundant, diversified molluscs.
Second Great Revolution (Considerable loss of fossils)							
Proterozoic		–	500	2000	Cool climate, volcanic eruptions, repeated, glaciations.	Primitive aquatic plants, algae, fungi and bacteria.	Shelled protozoans, coelenterates, flatworms, primitive annelids.
First Great Revolution (Considerable loss of fossils)							
Archaeozoic		–	2000	3, 600	Great volcanic activities, No recognizable fossils, indirect evidence of living things from some sedimentary deposits of organic material in rocks.		

THEORIES OF EVOLUTION

- To understand and explain the process of evolution various theories have been put forward by various scientists such as Lamarck, Darwin etc.

Lamarck's theory

- Lamarck's theory of evolution was published in '*Philosophie Zoologique*' in the year 1809. It is popularly known as **'The Inheritance of Acquired Characters in Organisms'**. It can be defined as 'the changes in structure or function of any organ acquired during the life-time of an individual in response to changes in the surrounding environment are inherited by its offsprings and keep on adding up over a period of time'.
- These changes lead to the origin of new species. It comprises of four propositions or assumptions - internal vital force, effect of environment and new needs, use and disuse of organs and inheritance of acquired characters.

Darwin's theory of natural selection or Darwinism

- The theory of natural selection was announced on June 30, 1858 by the English naturalist **Charles Darwin (1809-1882)** and **Alfred Russel Wallace (1823-1913)** in the paper **'Origin of Species by Means of Natural Selection'**. This theory is also known as **Darwin-Wallace theory**. In 1859, Darwin published his observations and conclusions. This theory is based on the following five propositions:

(a) **Overproduction or enormous fertility**

Living beings have an innate ability of producing their own progeny for the continuity of race. It has been observed that more individuals of each kind are produced than could possibly survive.

(b) **Struggle for existence**

According to Darwin, individuals multiply in geometric ratio whereas space and food remain almost constant. Therefore, there is an intense competition and struggle to ensure living and to obtain maximum amount of food and suitable land. As a result of struggle for existence, variability and inheritance, generations become better adapted to the environment.

(c) **Variations and heredity**

The everlasting competition among the organisms has compelled them to change according to the conditions so that they can utilize the natural resources and can survive successfully. Therefore, it is difficult to find out any of the two individuals alike. Even the progeny of the same parents are not exactly alike in all respects. These differences are known as variations.

Certain variations appeared in the parent generation continue to appear in the progeny generation. These variations are known as **heritable variations and form the raw material for evolution.**

(d) **Survival of the fittest or natural selection**

During the struggle for existence only those individuals could survive which exhibit such variations that are proved to be more beneficial in facing the hardships and rigours of environment or which change to adapt themselves to the changing conditions. **It has been called natural selection by Darwin and survival of the fittest by Herbert Spencer.**

- From above observations Darwin made certain conclusions and summarised them in the book '*Origin of Species by Natural Selection*' as follows :
  - As a result of struggle for existence, variability and inheritance, the successive generations tend to become better adapted to their environment. These adaptations, get preserved in the individuals of the species and ultimately lead to the origin of new species from the old ones.
  - The environment is ever changing and it leads to further changes and the appearance of new adaptations in the organisms. As natural selection continues, the latter descendants after several generations become markedly distinct from their ancestors.
  - Further more, certain members of a population with one group of variations may become adapted to environmental changes in one way, while others with a different set of variations may become adapted in a different way. As a result two or more species may arise from a single ancestral species.

Drawbacks of Darwin's theory

- He considered minute fluctuating variations as principal factors which are not heritable and are not part of evolution.
- He did not distinguish between **somatic** and **germinal variations** and considered all variations as heritable.
- Darwinism explains the 'survival of the fittest' but not the 'arrival of fittest'.
- He could not explain **overspecialisation** of particular structure which has led to the extinction of its possessors, *e.g.*, Saber toothed tiger.
- He proposed artificial selection which never lead to permanent variations.

Neo-darwinism

- Neo-Darwinism is refinement of original theory of natural selection to remove objections. According to Neo-Darwinism both mutations and natural selection are responsible for evolution.
- The chief Neo-Darwinians are **Weismann, Mendel** and **de Vries.** Neo-Darwinians believe that the main causes of difference in members of a species are – difference in genetic pattern; and influence of different environment.

Mutation theory

- The mutation theory was put forward in 1901 by **Hugo de Vries**, a Dutch botanist, to explain the mechanism of evolution.
- Features of mutation theory are following:
  - Mutations form the raw material for evolution.
  - Mutations appear suddenly and produce their effect immediately.
  - Mutants are markedly different from the parents and there are no intermediate stages between the two.
  - All mutations have a genetic basis and are, therefore, inheritable.
  - A single mutation may produce a new species.
  - Nature selects beneficial mutations and eliminates lethal mutations.
- Mutations are discontinuous variations, called '**sports**' by Darwin and '**saltatory variations**' by Bateson.
- Evolution for Darwin was gradual while deVries believed mutation caused speciation and hence called it saltation (single step large mutation).

Modern Synthetic Theory

- **Dobzhansky (1937)** in his book '*Genetics and Origin of Species*' provided the initial basis of synthetic theory. 'Modern Synthetic Theory of Evolution' was designated by **Huxley** in **1942.**
- Some of the important workers who have contributed to the modern synthetic theory are: **Dobzhansky, R.A. Fischer, J.B.S. Haldane, Sewall Wright, Ernst Mayr and G.L. Stebbins.**
- According to synthetic theory there are five basic factors involved in the process of organic evolution. These are:
  - **Genetic variation in population**
  - **Heredity**
  - **Natural selection**
  - **Reproductive isolation**
  - **Speciation**

MECHANISM OF EVOLUTION

- It is the population that evolves and not its individual members. The individual's role in the evolutionary process is to pass its genetic variation to its offspring.
- Mechanism of evolution involves three steps: **variations, their inheritance** and **natural selection.**

Variations

- Evolution occurs through the accumulation of genetic variations in the gene pool of population over long periods of time.
- The change in genes occurs in many ways such as **mutations, genetic drift, gene migration, non-random mating, gene recombination** and **hybridization**.

Mutations

- Gene mutation is a random change in the base sequence of a gene. It occurs by substitution, addition or deletion of one or more bases. The mutated gene may give rise to a new protein or may fail to produce any. This may change the phenotype (trait).
- Mutations can be of two types : **Chromosomal aberrations** and **genetic variations**. Aberrations occur by **deletion, inversion, translocation** and **duplication** of a chromosome segment. The chromosomal aberrations result in loss of genes, new positions of genes or addition of genes. Gene variation results in change in gene frequency.

Genetic drift

- The theory of genetic drift was developed by geneticist **Sewall Wright** in 1930. It is also called as **Sewall Wright Effect** or **scattering of variability**.
- The term genetic drift refers to chance elimination of the genes of certain traits independent of gene's useful or harmful effect when a section of population migrates or dies of natural calamity. It alters the gene frequency of the remaining population. Hence genetic drift is a mechanism of evolution that acts in concern with natural selection to change species characteristics over time. Two important examples of genetic drift are **bottleneck effect** and **founder effect**.
- **Bottle neck phenomenon :** A population may be formed of thousands of individuals but in the next season or next year only a relatively few individuals may survive. The few individuals form the progenitors for the future generation of the population which may multiply sporadically in the next generation and may decline after one or two generations. This yearly or seasonal phenomenon of cyclic fluctuation in population density causing periodic squeezing of some of the genes in a gene pool in random fashion is called Bottle Neck phenomenon. The term was used by **Stebbins**.
- **Founder effect :** When a few individuals or a small group of individuals from some large population invades a new or isolated geographical region, they become the **founders**. These founders carry on a limited portion of the parental gene pool. Their gene pool may contain certain alleles in a very low frequency or may lack a few alleles. The descendants of the founder *i.e.*, the founder population or marginal isolates in new area will tend to have allele ratios similar to the founders rather than to the source population. The resemblance of the descendents to the founders is called founder effect or founder principle by **Mayr**.

Gene migration (Gene flow)

- If the migrating individuals interbreed with the members of local population, these may bring many new alleles into the local gene pool of the host population. This is called **gene migration**.
- This addition or removal of alleles when individuals enter or leave a population from another locality is called **gene flow**.

Non-random mating

- Repeated mating between individuals of certain selected traits changes the gene frequency. The selection of more brightly coloured male bird by a female bird may increase the gene frequency of bright colour in the next generation.

Gene recombination

- It occurs due to the following reasons :
  - Dual parentage.
  - Independent assortment of chromosomes.
  - Crossing over during meiosis.
  - Random fusion of gametes.
  - Formation of new alleles.

Hybridization

- It is the crossing of organisms which are genetically different in one or more traits (characters). It helps in intermingling of genes of different groups of the same variety, species and sometimes different species.
- All the above factors produce genetic variation in **biparental reproduction. In monoparental reproduction, chromosomal aberrations and gene mutations are the only sources of genetic variations.**

Inheritance of variation

- The transmission of characteristics or variations from parent to offspring is called heredity which is an important mechanism of evolution.
- Organisms possessing hereditary characteristics that are helpful, either in the animal's environment or in some other environment, are favoured in the struggle for existence. Thus, the offspring are able to benefit from the advantageous characteristics of their parents.

Natural selection

- It is **differential reproduction** which means some members of population have traits (genes) that enable them to grow up and reproduce at a higher rate and leave more surviving offsprings in the next generation than others, *i.e.*, they are selected by nature. If differential reproduction continues for many generations, genes of the individuals which produce more offspring will become predominant in the gene pool (total gene content of a whole species) of the population.

Types of natural selection

- Based upon different organism-environment relationships, following different kinds of natural selections have been recognized -
  (i) Stabilizing selection

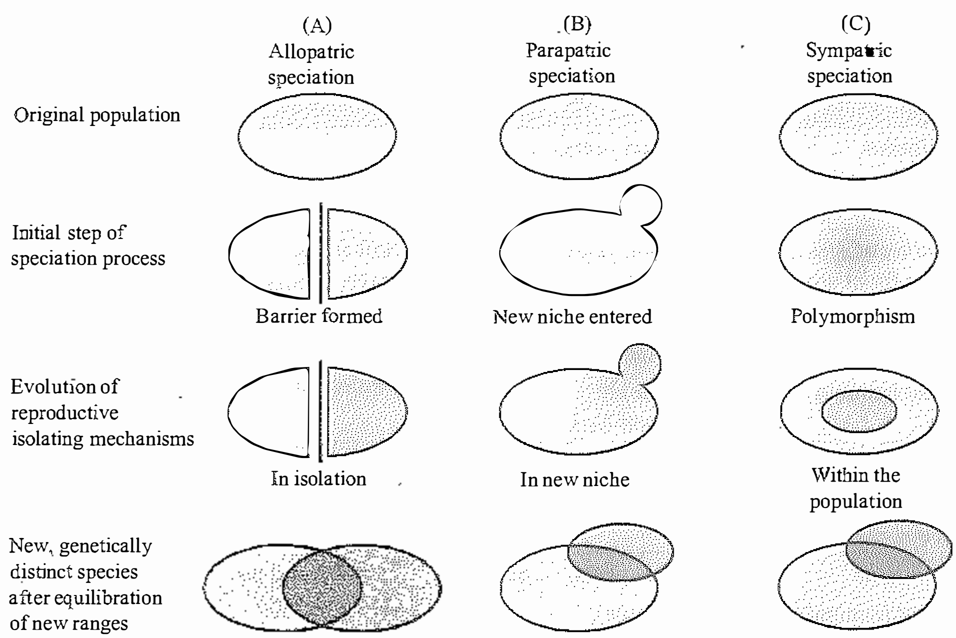
(ii) Directional selection

(iii) Disruptive selection

- **Stabilizing selection or Balancing selection :** It acts in the absence of large scale environmental change or directional changes for long period. It favors an intermediate form and eliminates the extreme variants.
- **Directional selection or Progressive selection :** It produces a regular change within a population in one direction in respect to certain characteristics. This is due to change in the environment in a particular direction. It favours individuals that change in response to the environmental change and become best adapted to new environmental or ecological condition. It favours the phenotype which is non-average or extreme and then pushes the phenotype of the population in that direction.
- **Disruptive selection or Diversifying selection :** It is just the opposite of stabilizing selection *i.e.*, the extremes have more adaptable phenotypes than the average ones. Consequently, the original population is disrupted into two more separate groups that later evolve into new species. If disruptive selection results in many new species then it is termed as **adaptive radiation**. This kind of selection is rare.

Speciation

To understand speciation, it is important to know about species. A species is a group of populations through which genes can flow and whose offspring have a fitness equal to the parents. As evolution progresses, gene flow is eventually stopped between one population and the species behaves as a reproductively distinct from other populations of the species from which it diverged. This is called phyletic evolution or anagenesis. Alternatively the population could evolve into two distinct species that exist simultaneously. This is called true speciation or cladogenesis.



(A) Allopatric speciation - physical barrier divides population, ranges do not touch or overlap, no gene flow.

(B) Parapatric speciation - founding population leaves original, ranges touch but do not overlap significantly, gene flow usually small.

(C) Sympatric speciation - speciation occurs without physical separation, ranges overlap significantly, gene flow is not prevented by geography.

HARDY-WEINBERG PRINCIPLE

- The genetic equilibrium is defined as– "The relative frequencies of various kinds of genes in a large and randomly mating sexual panmictic population tend to remain constant from generation to generation in the absence of mutation, selection and gene flow." **This is called Hardy-Weinberg principle or Hardy-Weinberg equilibrium.** Hardy -Weinberg principle is an expression of the notion of a population in 'genetic equilibrium' and is the basic principle of **population genetics**.
- In a population at equilibrium, for a locus with two alleles, D and d having frequencies of p and q, respectively, the genotype frequencies are: DD = p^2, Dd = 2pq, and dd = q^2.
- The two formulae are –

$p^2 + 2pq + q^2 = 1$, $p + q = 1$

where,

p = Frequency of the dominant allele in the population.

q = Frequency of the recessive allele in the population.

p^2 = Percentage of homozygous dominant individuals.
q^2 = Percentage of homozygous recessive individuals.
2pq = Percentage of heterozygous individuals.
I = Sum total of all the allelic frequencies.

- Hardy-Weinberg's law describes a theoretical situation in which a population is undergoing no evolutionary change.
- Salient features of Hardy-Weinberg principle : (i) random mating, (ii) large population size, (iii) biparental mode of reproduction and (iv) homogeneous age structure. The gene frequency will remain static only in the absence of evolutionary forces like mutations, selection, genetic drift and migration.

Significance of Hardy-Weinberg principle

- The Hardy-Weinberg law is important primarily because it describes the situation in which there is genetic equilibrium and no evolution. Thus :
  - It provides a theoretical baseline for measuring evolutionary change.
  - The equilibrium tends to conserve gains which have been made in the past and also to avoid too rapid changes.
  - Equilibrium maintains heterozygosity in the population.
  - Equilibrium prevents evolutionary progress.
- Factors affecting Hardy-Weinberg's principle are : (i) gene flow/ gene migration, (ii) genetic drift, (iii) genetic recombination, (iv) mutations and (v) natural selection.

HUMAN EVOLUTION

- Human evolution, or **anthropogenesis**, is the part of biological evolution concerning the emergence of *Homo sapiens sapiens* as a distinct species from other hominids, great apes and placental mammals.

Table : Summary of Human Phylogeny

	Name	Age of Appearance	Cranial capacity (cm^3)	Food/ Posture	Important features
1.	Parapithecus	40 million years, (Oligocene)	–	–	Has characters of tarsiers, and anthropoid called monkey ape, common ancestor of man-ape-monkey.
2.	*Dryopithecus africanus* (Earliest fossil ape)	25 million years, (Miocene)	–	Soft fruits, leaves, knuckle walker	Muzzle and canines large, arms and legs equal-sized.
3.	*Ramapithecus* (Earliest hominid fossil)	15 million years, (Miocene) in Africa and Asia	–	Seeds, nuts, semi-erect	Canines small, molars large, arboreal man like dentition.
4.	*Australopithecus africanus* (First ape-man)	5 million years, (Pliocene)	450	Essentially ate fruits, fully erect, 1.5 m tall.	Foramen magnum ventral, canines small, hunted small game.
5.	*Homo habilis* (The first hominid tool maker)	2 million years, (Pleistocene), Early in Africa	650-800	Probably did not eat meat, fully erect	Canines small, earliest stone tools, hunted large game, Bipedal gait, cave-man led to community life.
6.	*Homo erectus* (The erect man or Java man)	1.5 million years, (Mid Pleistocene)	900	Probably ate meat 1.50-1.80 m tall	Thick, low forehead; brow ridges, used stone and bone tools, hunted big game.
7.	*Homo neanderthalensis* (The Neanderthal man, First civilised man)	100,000 to 40,000 years (Pleistocene)	1400	Omnivorous, 1.5-1.66 m tall	Cave dweller, made flint flake tools, used hides as clothes, buried the dead, speech centres had developed, used syllabic language, prognathus face, chin absent.
8.	*Homo sapiens fossilis* (The fossil modern man or Cro Magnon man)	34,000 years Recent (Holocene)	1650	Omnivorous, 1.8 m tall	Strong jaws with teeth close together, wisdom teeth, cave-dweller, paintings and carvings in caves, had art and culture, orthognathous face, broad pelvic basin, prominent chin.
9.	*Homo sapiens sapiens* (The living modern man)	25,000 years (Holocene)	1300-1600	Omnivorous, 1.5-1.8m tall	Backbone with 4 curves; most intelligent; has art, culture, language.

CONCEPT MAP

Origin of Life

Theories of origin of universe

Nebular Hypothesis

It was proposed by Kant-Leplace according to which earth originated about 4.5 - 5 billion years ago from a gaseous cloud solar nebula.

Big bang Theory

According to this theory of Abbe Lemaitre universe formed by a big bang (thermonuclear expansion) of a dense entity.

Chemical theory of origin of life

- Oparin – Haldane's of chemical origin theory is most widely accepted theory of origin of life. It involves some basic steps that are:
- **Formation of inorganic molecules**
- From the gases present in early earth's atmosphere.
- **Formation of simple organic compounds**
- From the inorganic compounds formed in previous step.
- **Spontaneous formation of complex organic molecules**
- Simple organic molecules combined to from large organic complex biomolecules like starch, proteins, fatty acids.
- **Spontaeous formation of molecular aggregates, coacervates, eobionts and first living cell**
- Complex organic compounds synthesized on primitve earth grouped together spontaneously and due to intermolecular attraction formed large collodial aggregates called **coacervates** or **microspheres** which turned into **eobionts** (controlled by nucleic acids). These developed cell membrane and formed first living cells or **prokaryotes**.

Eukaryotes (Unicellular)

Evolution

(Latin *evolvere*-to unroll). Multicellular organisms evolved from tiny eukaryotic unicellular ones.

Evidences of evolution

Morphological and anatomical

Comparative studies of morphology and anatomy, homology of organisms provide evolutionary proofs, *e.g*, vestigial organs, atavism etc.

Embryological

Comparative study of embryonic development of various organisms shows various similarities and resemblance to embryos of lower organisms indicating evolution (Biogenetic law of Haeckel)

Paleontological

Paleontology is the study of fossils (preserved remains of dead organisms). It provides most direct and reliable evidences of evolution.

Connecting links

Connecting links are living organisms with characteristics intermediate between two groups, *e.g.*, *Euglena* (link between plants and animals).

Molecular and physiological

Various physiological processes, cellular structure, biochemistry, genetic composition, etc. also provide evolutionary evidences, e.g., blood plasma proteins.

Theories of evolution

Lamarck's Theory

It says that "The changes in structure or function of any organ are acquired during the lifetime of an individual by use or disuse of that organ and are inherited" causing evolution.

Darwin's Theory

It says that variations occur in organisms and useful among them are selected by nature (*i.e.*, natural selection) and get accumulated in the organism. This leads to evolution.

Mutation Theory

This theory put forward by Hugo de Vries says that evolution is a discontinuous, saltatory process that occurs due to sudden inheritable variations.

Modern Synthetic Theory

According to it five factors : genetic variations, heredity, natural selection, reproductive isolation and speciation lead to evolution.

Mechanism of evolution

Evolution starts with generation of variations. Variations in a population may occur by mutations, genetic drift, gene migration, gene recombination, hybridization, etc. Out of these variations inheritable variations undergo natural selection and the individual with highest survival value in the present environmental conditions evolve.

Human evolution

All human beings present today belong to a simple species *Homo sapiens* which has evolved bipedal locomotion high cranial capacity, opposable thumbs etc. and dominates today's life forms.